**The Seventh Memorial Workshop of Kazuhide Mori on Computational Science**

# Dynamic Properties of Dynein Movement

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The dynein causes two kinds of movements. One is a flagella movement that gives going forward power by flagella scroll [1–3]. Another is a cytoplasmic movement that is studied intensively now [4–11]. These movements are produced by an interaction between the dynein and microtubules [2,6,9]. We remember the measurement of force by the movement single active element [5,7,10,11]. It is also possible to apply the method of atomic trapping by laser power by its spot [12–14]. It is balanced with Lorentz force produced by electromagnetic field of the laser spot. [12–14]

The flagella movement can be described by curvature changes along the flagella lines. A flagella starts from the membrane of microscopic scale organ and makes a stroke like the ring wave of changing the direction. The curvature is line one so that it is proportional to the inverse value of circle radius.

We have a picture for the mechanics of dynein movement shown below. In this scheme, a dynein molecule (2.17 M-Daltons) is relatively large compared with surrounded small molecules such as water molecule (18 Daltons); the former is five orders of magnitude greater than the latter.

The velocity of a dynein movement is measured using fluorescent manner. It is 50–150 nm/sec in a wild type [11]. In flagella a relationship between beat frequency (f) and maximum shear angle ($\theta_{\max}$) is given as $f = 14/\theta_{\max}$ [2]. The velocity of moving on the microtubules depends on ATP concentration. Reference [9] gives 200–1000 nm/s for the case of 100 $\mu$M ATP + 1 mM AMPPNP. It means that large ATP concentration does not yield a large step on the microtubules. The relationship between velocity and force decreases almost linearly [5], but it increases in the small region in which velocity increases as force becomes large [5]. In such small areas the force is 0.4–0.8 pN for 5 $\mu$M ATP and 0.8–1.25 pN for 100 $\mu$M ATP [5].

The important point is that a dynein molecule gets the force from the ATP hydrolysis. The forces are 3.0–6.0 pN [11]. The reference [10] shows that step size 8.1 nm (force $>$ 1 pN) for 1 mM ATP, 8.0 nm (force $>$ 1 pN) for 10 $\mu$M ATP, and 8.6 nm (force $<$ 1 pN) for 20 $\mu$M ATP. It is difficult what magnitude of force is obtained by ATP hydrolysis, but rough estimation is possible considering entire force measurements.

A molecular weight of dynein is $2.74 \times 10^{-17}$ g. This value is too small to consider the weight of a dynein molecule explicitly in the model. The force produced by ATP hydrolysis is in the order of pico-newton [5,10,11]. Therefore, gravitational force becomes five orders of magnitude smaller than pico-newton. A friction force depends on the magnitude of velocity relative difference between dynein and surrounded small molecules in the cytoplasm. In the movement of macroscopic

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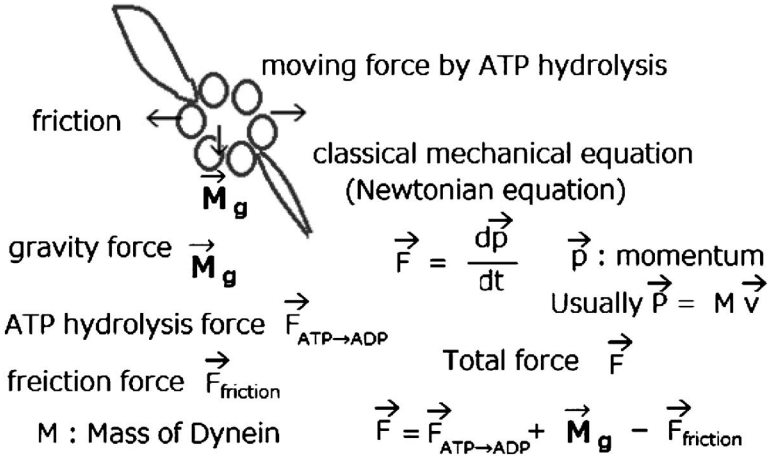


body in the gravity field, the investigated friction force have a linear dependence of velocity or square (or inner product) of velocity magnitude. Thus, it is a problem how about the magnitude of force produced by ATP hydrolysis. We here consider that a movement of a dynein follows mechanical way.

In this talk, we considered that the movement is caused in a simple mechanical manner, and forces are considered to be produced by the ATP hydrolysis, friction by surrounded small molecules in macroscopic form, and gravity. The magnitude of gravity force is small because a dynein molecule has very small weight as described above. We think that the major force is the one produced by ATP hydrolysis. The magnitude is estimated as the order of pico-newton ($1.0–1.2 \times 10^{-12}$ N). The magnitude of this force is the biggest in the forces we considered.

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